Modeling Propellant Tank Dynamics

Completed Technology Project (2011 - 2015)

Project Introduction

The main objective of my work will be to develop accurate models of self-pressurizing propellant tanks for use in designing hybrid rockets. The first key goal is to develop an accurate and computationally attractive equation of state for nitrous oxide. N2O is a popular self-pressurizing oxidizer but standard operating temperatures are close to the critical point and therefore the oxidizer's thermodynamic properties are non-ideal and difficult to predict. The next goal is to develop a dynamic model for the numerous processes occurring in an emptying tank. This includes heat and mass transfer between phases, heat transfer to and from the walls of the tank, and fluid dynamics induced by convection and the propellant flowing out of the tank. Third, extensive experimentation must be done in order to benchmark the model and assess the presence and importance of certain processes such as nucleation, boiling, and vaporization. Finally, a design study must be done in order to determine how the finalized model can best be used to increase the performance of hybrid rockets. Methods Previous works in the chemical engineering industry have identified proper functional forms for equations of state of varying accuracy and computational cost. However, when fitted to data for N2O, the empirical data used for the most commonly used model was incomplete and hence errors were introduced. By modifying a standard form slightly and by re-fitting the proper constants using a larger dataset, I will create a much better model. A dynamic model will be generated by first searching the literature for accurate expressions for heat and mass transfer through unsteady nucleation, boiling, vaporization, and condensation. In contrast, the current state of the art for propellant tank modeling includes only simple expressions for convection from flat plates, and an assumption of uniform temperatures. Experiments will then be conducted by building a custom tank that contains numerous temperature sensors, in addition to pressure and optical sensors. By measuring the temperature field throughout the tank and using the pressure data, I will be able to obtain an accurate global picture of the thermodynamic state of the nitrous oxide, and assess its uniformity. Optics will also be necessary in order to determine the presence and strength of nucleation and boiling within the tank. Using advanced optimization methods, the designs of hybrid rocket propulsion systems for various applications such as launch vehicles, sounding rockets, and in-space propulsion will be optimized. In this way, the benefits of using an accurate propellant tank model in the design process can be demonstrated. Significance Part of NASA's mission is to pioneer the future in space exploration. Hybrid rockets are a key component of that future because they will enable us to explore our solar system for a fraction of the cost of traditional rockets. This cost reduction is a result of both the inherent safety provided by a phase boundary between the solid fuel and liquid oxidizer, but also through the use of non-hazardous propellants like N2O. Nitrous oxide is an attractive oxidizer for hybrid rockets because it is self-pressurizing and therefore it can be pushed out of a propellant tank using only it's own high vapor pressure. This negates the need for turbopumps or inert gas pressurization systems,

Project Image Modeling Propellant Tank Dynamics

Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

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Anticipated Benefits

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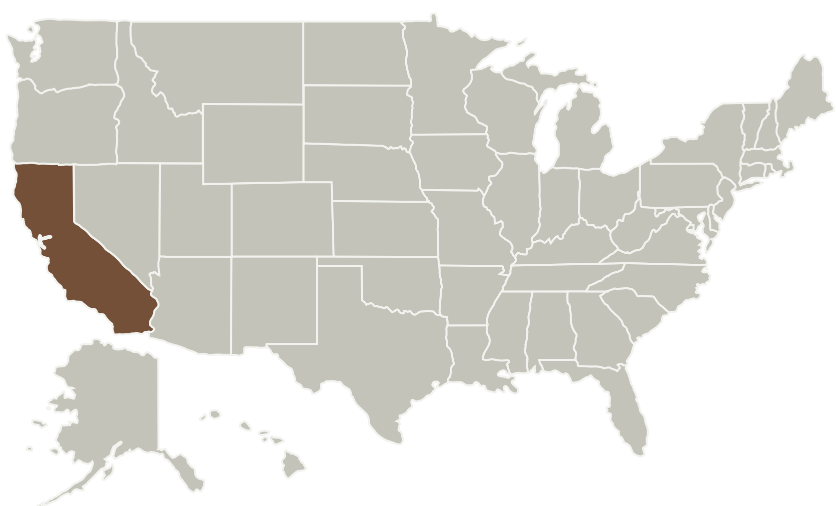
Primary U.S. Work Locations and Key Partners



Project Management

Program Director:
Claudia M Meyer

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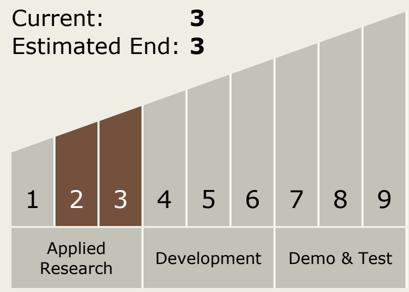
Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX01 Propulsion Systems
  └─ TX01.1 Chemical Space Propulsion
    └─ TX01.1.5 Hybrids

Primary U.S. Work Locations

California

Images

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Project Image Modeling Propellant Tank Dynamics
(https://techport.nasa.gov/image/1798)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html